Public Understanding of Climate Change in the United States

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This article considers scientific and public understandings of climate change and addresses the following question: Why is it that while scientific evidence has accumulated to document global climate change and scientific opinion has solidified about its existence and causes, U.S. public opinion has not and has instead become more polarized? Our review supports a constructivist account of human judgment. Public understanding is affected by the inherent difficulty of understanding climate change, the mismatch between people's usual modes of understanding and the task, and, particularly in the United States, a continuing societal struggle to shape the frames and mental models people use to understand the phenomena. We conclude by discussing ways in which psychology can help to improve public understanding of climate change and link a better understanding to action.

Keywords: risk perception, climate change perception, mental models, expert–novice differences

"Climate change" is the name given to a set of physical phenomena and of a public policy issue, sometimes also referred to as "global warming," even though climate change involves much more than warming. This article describes the development of scientific and public understanding[1] of climate change in the United States, focusing especially on the riddle of noncorrespondence: Why, as scientific understanding of climate change has solidified, has U.S. public understanding not, and instead become more polarized? It also considers the implications of this situation for the future of public understanding and action.

"Climate change" emerged as a public policy issue with improved scientific understanding of the phenomena involved, resulting in concerns. In 1959 an observatory on Mauna Loa, Hawaii, recorded a mean level of atmospheric carbon dioxide (CO_2) of 315 parts per million, well above the highest concentration—no more than 300 parts per million—revealed in the 420,000-year-old ice-core record. By the end of the 1970s, CO_2 levels had reached 335 parts per million (Hecht & Tirpak, 1995). The National Research Council, asked to investigate the subject, suggested, "If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible" (Climate Research Board, 1979, p. vii). In 1987, Congress passed the Global Climate Protection Act and directed the Environmental Protection Agency to propose to Congress a coordinated national policy on global climate change and the Secretary of State to coordinate diplomatic efforts to combat global warming. The Global Change Research Act of 1990 established a major national research program to study global environmental change, including climate change, its causes, its effects, and possible responses.

Scientific Understanding of Climate Change

Scientists' understanding of climate change has evolved over more than 150 years through a process of collective learning that relies on the accumulation of observational data; the formation, testing, and refinement of hypotheses; the construction of theories and models to synthesize knowledge; and the empirical testing of hypotheses, theories, and models (National Research Council, 2010a). The understanding of the scientific community is captured in carefully peer-reviewed collective assessments of the evidence, including those of the Intergovernmental Panel on Climate Change (IPCC). The most important recent assessments, particularly from a U.S. standpoint, are those of the U.S. Global Change Research Program (Karl, Melillo, & Peterson, 2009) and the National Research Council (2010a). These assessments support the following conclusions with high or

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[1] By "understanding" of climate change, we mean a set of cognitions about what "climate" and "climate change" mean, what the essential attributes of climate are, how these attributes are connected to each other, what causes climate change, what the consequences of climate change will be, and the degree of confidence that should be placed in various knowledge claims about climate change. "Public understanding" refers to the distribution of understandings in a general population.

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very high confidence[2] (National Research Council, 2010a, p. 28):

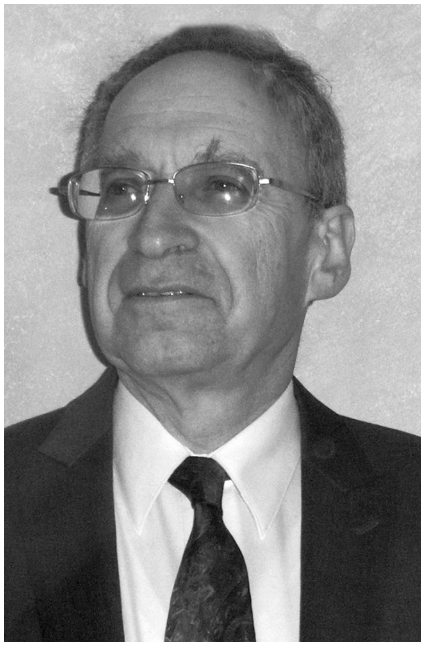
- "Earth is warming . . . . the planet's average surface temperature was 1.4 °F (0.8 °C) warmer during the first decade of the 21st century than during the first decade of the 20th century, with the most pronounced warming over the past three decades."
- "Most of the warming over the last several decades can be attributed to human activities," the most important of which is the burning of coal, oil, and natural gas for energy. "Natural climate variability [that] leads to year-to-year and decade-to-decade fluctuations . . . cannot explain . . . the long-term warming trend."
- "Global warming is closely associated with a broad spectrum of other climate changes, such as increases in the frequency of intense rainfall, decreases in Northern Hemisphere snow cover and Arctic sea ice, warmer and more frequent hot days and nights, rising sea levels, and widespread ocean acidification."
- "Individually and collectively, . . . these changes pose risks for a wide range of human and environmental systems, including freshwater resources, the coastal environment, ecosystems, agriculture, fisheries, human health, and national security, among others."
- "Human-induced climate change and its impacts will continue for many decades, and in some cases for many centuries. . . . The ultimate magnitude of climate change and the severity of its impacts depend strongly on the actions that human societies take to respond to these risks."

Increasing certainty about these fundamental climate change phenomena is reflected in ever more definitive language in consensus judgments of the scientific community, such as the IPCC Assessment Reports of 1990, 1995, 2001, and 2007 and other independent assessments of the evidence (e.g., Karl et al., 2009; National Research Council, 2010a, 2011). Of 1,395 signatories of major public statements endorsing or rejecting these tenets on scientific grounds, 97%–98% of those who are active and prominent climate scientists were endorsers[3] (Anderegg, Prall, Harold, & Schneider, 2010).

Many other important aspects of climate change, particularly about its consequences, are less well established. Estimates of these have various degrees of uncertainty. Uncertainties involve how much warming will result from a given level of emissions (called "climate sensitivity") and, given a specific amount of warming, which effects on natural and human systems will occur when, where, and to what degree. The uncertainties are due to the complexity of the system, the incomplete basic understanding of some of its parts and of their interactions, the fact that the system is rapidly moving outside the bounds within which historical observations exist, and the fact that human activities will change both the trajectory of climate change and the vulnerability of the affected people and places in ways that are not fully predictable. Some consequences, such as eventual loss of habitat for the polar bear, can be predicted with fairly high probability; others, such as the geographic locations of future extreme storms or heat waves, are much less predictable. Uncertainty is not restricted to negative consequences of climate change but also extends to predictions about consequences that might have positive utility for specific regions or time periods, such as sections of Canada or Siberia becoming more habitable or arable. Of particular concern to some scientists is the possibility of catastrophic climate events as the result of changes in a complex and incompletely understood system that has moved outside the bounds of historical experience. Climate catastrophes may be highly unlikely, but their probabilities cannot be confidently estimated, so they cannot be ruled out. These possibilities have led many scientists to become seriously concerned about climate change as a threat to the natural environment and to human well-being (e.g., Hansen, 2009). They have also led many national security

[2] According to the report (National Research Council, 2010a), "high confidence indicates an estimated 8 out of 10 or better chance of a statement being correct, while very high confidence . . . indicates a 9 out of 10 or better chance" (p. 27).

[3] Anderegg et al. (2010) compiled a list of 903 researchers who endorsed (signed) one or more of four public statements about anthropogenic climate change that paraphrased the above tenets in different ways. They similarly identified 472 researchers who endorsed (signed) one or more of 12 reputable statements that strongly dissented from these tenets. Climate expertise and scientific prominence as measured by number of climate-relevant publications and the number of citations to the researcher's four top-cited publications (not restricted to climate) were significantly lower for the second group than for the first group. When researchers were rank-ordered by expertise (number of climate publications), only between 2% and 3% of top-ranked researchers (top 50, top 100, top 200) were signers of public statements that disagreed with these tenets.



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experts to become concerned about threats to national security through mass climate-driven international migrations or increased instability in fragile states (CNA Corporation, 2007).

The American Public's Understandings of Climate Change

A time series of public opinion polls in the United States gives a rough picture of public understanding of some key aspects of climate change since the late 1990s. Figure 1 shows what percentage of the American public has endorsed the following three statements over a period from 1997 to 2010:[4] Global warming (a) is beginning or has begun, (b) is due more to human activities than natural causes, and (c) will pose a serious threat to them or their way of life in their lifetime. Figure 1 shows that endorsement of these statements by the public has fluctuated considerably over this time period, in contrast to the monotonic increases in acceptance of these ideas among climate scientists over this same time period. Scientists and nonscientists now differ sharply in how strongly they hold these views. A Pew Research Center (2009) poll found that while 84% of scientists said the earth was getting warmer because of human activity such as burning fossil fuels, just 49% of nonscientists in this U.S. representative sample held this view.

Comparative data from global surveys indicate that acceptance of the idea that climate change is anthropogenic is not only less prevalent among the American public than among American scientists but is also less prevalent among the American public than among nonscientists in many other countries. Gallup polls in 2007 and 2008 show that 49% of the American public endorse this idea, similar to the percentage in the United Kingdom (48%), but less than the percentages in most other countries surveyed, including Japan (91%), Argentina (81%), Italy (65%), Sweden (64%), Canada (61%), and Germany (59%) (Pelham, 2009).

Why No Convergence in Scientists' and Nonscientists' Understandings?

Physical, psychological, and social factors together help explain why public understanding in the United States has not tracked scientific understanding. First, climate change as a set of physical phenomena in interaction with their human causes and consequences is intrinsically challenging to understand. Second, scientists and nonscientists have different ways of understanding these phenomena, which makes divergence of beliefs possible. Moreover, when people apply their conventional modes of understanding to climate change, they are likely to be misled. Third, nonscientists' views in the United States and some other countries are being shaped by an ongoing struggle to impose conceptual frames on climate change as a policy issue, in which a well-funded and orchestrated campaign has had success in promoting frames that are at striking variance with the scientific evidence and the solidifying scientific consensus.

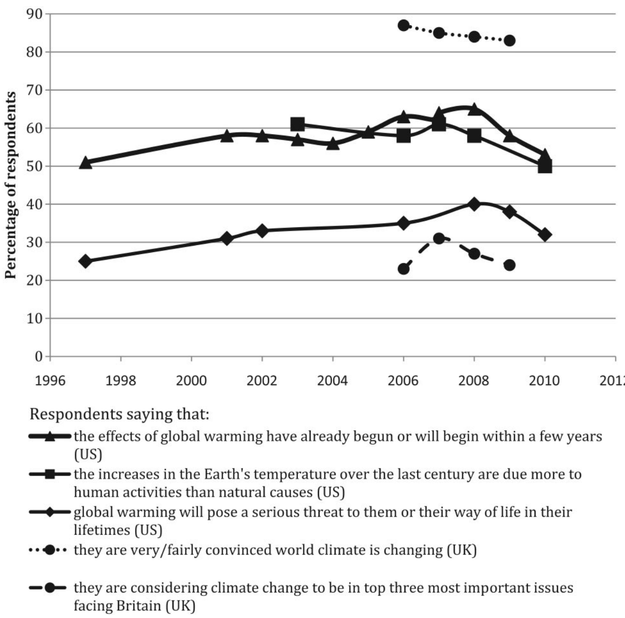
Physical Phenomena: Climate Change Is Intrinsically Difficult to Understand

Some fundamental attributes of climate change make it hard to understand.[5] The main causes of climate change (greenhouse gases) are invisible, its impacts are geographically and temporally distant for most Americans, and, as discussed below, its signals are hard to detect (Moser, 2009; National Research Council, 2009). Unlike a heat wave or a hurricane, climate change is not a single hazard. A small number of climate "drivers"—fossil fuel consumption being by far the most important—can cause a multiplicity of causally linked hazards (National Research Council, 2010a). Thinking about climate change in terms of any one or two of these hazards leads to an underestimate of the total threat. Another key attribute is the long-lasting environmental residence of the main greenhouse gases (Solomon, Plattner, Knutti, & Friedlingstein, 2009). These gases are unlike the air pollutants that cause smog; reducing emissions will not quickly "clear the air." Long residence times are hard to understand; well-educated nonspecialists systematically underestimate the degree to which carbon dioxide emissions must be reduced in order to stabilize overall concentrations (Sterman & Booth Sweeney, 2007). Another climate fact of life is that climate history is a poor

[4] The Gallup poll data shown here were collected in telephone interviews with nationally representative random samples of adults (age 18 years or older) ranging in size from 1,000 to 1,060, and with interviews conducted during March of each year. Gallup weights the sample data to ensure that answers are representative of the U.S. adult population.

[5] For a detailed discussion of the physical and social complexities of climate change, see National Research Council (2011), especially Chapter 3.

Figure 1
Percentages of American (Solid Lines) and British (Dashed Lines) Survey Respondents Endorsing Various Statements About Global Climate Change



Note. Data for American respondents are from nationally representative Gallup polls taken between 1997 and 2010. Data for United Kingdom (UK) respondents are from nationally representative National Statistics Opinions Surveys taken between 2006 and 2009.

guide to the future and will become a poorer guide the farther one thinks into the future. On top of these difficulties in understanding climatic processes, the impacts are hard to understand. Changes in emissions may have effects anywhere in the world, and the consequences are not distributed evenly, fairly, or predictably and depend on other social, economic, and environmental changes occurring over the same period. For example, the impact of a future coastal storm on human and ecological systems will depend on what has been built along the coast and what early warning systems are in place. The coastal ecosystems that will be affected by ocean warming, acidification, and sea level rise are also stressed by pollution and invasive species.

Psychological Factors: The Potential for Systematic Misconceptions

Scientists and nonscientists develop their understandings in different ways. Climate scientists have developed understanding over generations by using multiple methods that scientists typically use to guard against error: (a) observations and experiments that build and test fundamental theories and concepts, such as the laws of physics; (b) systematic observation and measurement of climate phenomena; (c) mathematical models that incorporate theories and observational data and are tested against new data; (d) systems of checking measurements and peer-reviewing research studies to catch errors; and (e) scientific debate and deliberation about the meaning of the evidence, with special attention given to new evidence that calls previous ideas into question. Scientific communities sometimes organize consensus processes such as those used in the IPCC and National Research Council studies to clarify which conclusions are robust and which remain in dispute. These methods lie at the core of science, and deliberative methods are key to developing understanding at the frontiers of science—including climate science (Longino, 1990). Although these methods do not prevent all error, and errors in climate change research—as in other areas of scientific inquiry—have occurred and can be expected to occur in the future, the scientific methods clarify the unresolved issues and allow for continuing correction of error.

Nonscientists' ways of understanding climate change leave them more vulnerable to systematic misunderstanding. Personal experience can easily mislead (Weber, 1997); simple mental models are likely to be wrong when applied to climate change (Bostrom, Morgan, Fischhoff, & Read, 1994); and judgment can be driven more by affect, values, and worldviews than by evidence (Slovic, 1987). For a valid understanding of climate change, most people must rely on secondary sources. But as discussed below, these information sources are not always trustworthy.

The power and limitations of personal experience. Personal experience is a powerful teacher, readily available to everyone from an early age. Decisions based on personal experience with the outcomes of actions (e.g., touching a hot stove or losing money in the stock market) involve associative and affective processes that are fast and automatic (Weber, Shafir, & Blais, 2004). However, learning from personal experience can lead to systematic bias in understanding climate change. First, there are serious problems detecting the signal. In most U.S. locales at this time, it is virtually impossible to detect the signal of climate change from personal experience, amid the noise of random fluctuations around the central trend (Hansen, Sato, Glascoe, & Ruedy, 1998). Second, people are likely to be misled by easily memorable extreme events. Such events have a disproportionate effect on judgment (Keller, Siegrist, & Gutscher, 2006) even though they are poor indicators of trends. Extreme events by definition are highly infrequent, and it takes a long time to detect a change in the probability of an event that occurs, on average, once in 50 years or less frequently. The likelihood of an increase in the frequency or intensity of extreme climate-related events large enough to be noticed by humans will be small for some time in many regions of the world. Even individuals whose economic livelihood depends on weather and climate events (e.g., farmers or fishers) might not receive sufficient feedback from their daily or yearly personal experience to reliably detect climate change, though recent surveys conducted in Alaska and Florida (two states in which the climate signal has been relatively strong) show that such personal exposure greatly increases the concern and willingness of citizens in these states to take action (Arctic Climate

Impact Assessment, 2004; Leiserowitz & Broad, 2008).[6] These studies are noteworthy for examining people's attempts to learn about climate change from personal experience, providing direct empirical evidence about the power as well as the shortcomings of this form of learning in this domain, rather than extrapolating from results of research in other domains.

Third, experiential learning tends to bias the public's understanding because of a tendency to over-weight recent events (Hertwig, Barron, Weber, & Erev, 2004). The evaluation of probabilistic outcomes follows classical reinforcement learning models, in which positive (negative) consequences increase (decrease) the likelihood of a behavior that gave rise to them. Such learning processes give recent events more weight than distant events, which is adaptive in dynamic environments where circumstances change with the seasons or other cycles or trends (Weber et al., 2004). Because extreme events have a small probability of having occurred recently, they usually have a smaller impact on the decision than their objective likelihood of occurrence would warrant. But when they do occur, recency weighting gives them a much larger impact on judgment and decision than their probability warrants, making decisions from experience more volatile across past outcome histories than decisions from description (Yechiam, Barron, & Erev, 2005). As a result, nonscientists can be expected to overreact to rare events like a hurricane or a heat wave (Li, Johnson, & Zaval, 2011) but most of the time to underestimate the future adverse consequences of climate change. Beliefs in climate change have been shown to be affected by local weather conditions (Li et al., 2011), and a relatively cool 2008 may have influenced the drop in American concern about climate change in 2008–2009 (Woods Institute for the Environment, 2010). Confusing weather with climate increases the potential for these sorts of error (Weber, 2010). Climate scientists can also overreact to single vivid events, but their greater reliance on analytic processing, accumulations of data, statistical descriptions and model outputs, and scientific deliberation and debate can be expected to dampen this tendency. Without such correctives, nonscientists are more likely than scientists to accept evidence that confirms preexisting beliefs and to fail to search out disconfirming evidence (Evans, 1989). The scientific method can be seen as a cultural adaptation designed to counteract the emotionally comforting desire for confirmation of one's beliefs, which is present in everyone (M. Gardner, 1957).

Finally, nonscientists differ from scientists in the way they react to uncertainty. Rather than using probability theory to gauge and express the degree of belief in possible future events and to incorporate new evidence, nonscientists respond to uncertainty in ways that are more emotional than analytic (Loewenstein, Weber, Hsee, & Welch, 2001) and in qualitatively different ways depending on whether the uncertain events are perceived as favorable or adverse (Smithson, 2008). Nonscientists prefer concrete representations of uncertainty that relate to their experience (Marx et al., 2007). To satisfy this preference, some scientists translate probabilistic forecasts into a small set of scenarios (e.g., best- to worst-case) to facilitate strategic planning by professional groups such as military commanders, oil company managers, and policymakers (Schoemaker, 1995).

The limits of simple mental models. Simple mental models help people comprehend complex phenomena, but incorrect mental models can cause serious problems. This latter scenario has commonly occurred with respect to climate change. Researchers have been studying mental models of climate change since the early 1990s and have identified several ways in which many nonscientists' mental models diverge from those of climate scientists (e.g., Bostrom et al., 1994; Kempton, 1991; Reynolds, Bostrom, Read, & Morgan, 2010). When climate change first emerged as a policy issue, people often confused it with the loss of stratospheric ozone resulting from releases of chlorofluorocarbons. This view has become less prevalent as the "ozone hole" issue receded from the news pages and public attention. However, confusion of climate with weather and confusion of the causes of climate change with the causes of "pollution" remain at least as prevalent as they were in the early 1990s despite advances in the science of climate change and continuing efforts to explain the science to nonscientists (Reynolds et al., 2010).

The fairly widespread but false beliefs that recycling household waste and tightening regulation on air pollutants such as sulfur and nitrogen oxides would help ameliorate climate change (Kempton, 1991; Reynolds et al., 2010) are consistent with a mental model that fails to distinguish between climate change and general "pollution." The confusion of greenhouse gases with more familiar forms of pollution is especially troublesome because it supports the incorrect inference that "the air will clear" soon after emissions are reduced. But unlike familiar air pollutants, which stay airborne for only a short time, most greenhouse gases continue to warm the planet for decades or centuries after they are emitted (Solomon et al., 2009).

Another important role of mental models is that they shape climate expectations. For example, early English settlers in North America assumed that climate was a function of latitude, so they expected Newfoundland, which is south of London, to have a moderate climate. Despite repeated experiences of far colder temperatures and resulting crop failures, colonists clung to their expectations that were based on latitude, and they generated ever more complex explanations for these deviations from expectations (National Research Council, 1999). In a more recent example, farmers in Illinois were asked to recall salient temperature or precipitation statistics during the preceding seven growing seasons (Weber, 1997). Those farmers who believed that their region was undergoing climate change recalled temperature and precipitation trends consistent with this expectation, whereas those farmers who believed in a constant climate, recalled temperatures and precipitations consistent with that belief. Both groups showed similar degrees of error in their weather event memories, but

[6] A recent study of United Kingdom residents similarly found that recent personal experience with a climate change impact, namely local flooding, increased people's concern about climate change and their willingness to conserve energy (Spence, Poortinga, Butler, & Pidgeon, 2011).

their mental models of either constancy or change in climate variables biased the direction of their errors in perceptions and memory.

Cognition driven by affect, values, and worldviews. Evidence from cognitive (Sloman, 1996), social (Chaiken & Trope, 1999), and clinical (Epstein & Pacini, 1999) psychology indicates that judgments and decisions are influenced by associative and affective processes as much or more than by analytic processes, a distinction that has also been applied to judgments and choices in the climate change domain (Weber, 2006, 2010). The human associative processing system is evolutionarily older and operates quickly and automatically. It maps experienced uncertain and adverse aspects of the environment into affective responses (e.g., fear, dread, anxiety) and thus represents risk as a feeling (Loewenstein et al., 2001). This contrasts with analytic processes, which work by algorithms and rules (e.g., the probability calculus, Bayesian updating, and formal logic) that must be taught explicitly, operate more slowly, and require conscious effort and control. Climate scientists are trained to (and by and large do) attempt to base their judgments on analytic processing of large amounts of information. Nonscientists, on the other hand, typically rely on more readily available associative and affective processing. This tendency opens judgments of risk to influence by the way a particular hazard is labeled. For example, reports about "mad cow disease" elicit greater fear than reports about incidences of bovine spongiform encephalitis (BSE) or Creutzfeld-Jacob disease, the more abstract, less affect-laden scientific labels for the same disorder (Sinaceur, Heath, & Cole, 2005). This is not to say that scientists are always immune to the influence of nonrational processes, and examples of systematic biases in prediction exist in such areas as energy use (Shlyakhter, Kammen, Brodio, & Wilson, 1994) and climate science (Morgan & Keith, 1995).

Climate change is a relatively new, emerging attitude object (Stern, Dietz, Kalof, & Guagnano, 1995). Several lines of research converge on the conclusion that fundamental values and worldviews help shape how people develop attitudes about such phenomena. An affective dimension of attitudes is evident in the process of moral norm activation (Schwartz, 1977). People experience a sense of obligation to act (a personal moral norm) when they are aware of negative consequences to others from some state of affairs and ascribe responsibility to themselves for those consequences. This process affects concern with environmental risks (Dunlap & Van Liere, 1978; Stern, Dietz, & Black, 1985), including those of climate change (Dietz, Dan, & Shwom, 2007). The norm-activation process is connected to personal values (Schwartz, 1994), with "self-transcendent" values linked to environmental concerns through beliefs about consequences for others and about personal responsibility (Stern, Dietz, Abel, Guagnano, & Kalof, 1999). A related analysis rooted in anthropology links environmentalism to egalitarian views (Dake, 1991; Douglas & Wildavsky, 1982; O'Connor, Bord, & Fisher, 1999). Judgments of environmental risks also relate to broad environmental worldviews (e.g., adherence to the New Ecological Paradigm; see Dunlap & Van Liere, 1978; Stern, Dietz, & Guagnano, 1995).

Judgments of the riskiness of physical and environmental processes are strongly affected by perceived qualitative characteristics of the hazards, which can evoke affective reactions. These characteristics have been described in a two-dimensional space representing the degree to which hazards are familiar versus dreaded and known versus unknown (Slovic, 1987). These affective aspects of cognition are the basis of rhetorical appeals used in climate policy debates, as discussed below.

Social Factors: The Struggle to "Frame" Climate Change

Because it is hard to understand climate change from personal experience, people often rely on others presumed to be more expert to answer their questions about climate change. For the most part, they do not go to climate scientists directly but rather to intermediary sources, predominantly in the mass media, that present information and opinions in language and graphics that are easy to comprehend (Soroka, 2002). For most Americans, exposure to "climate change" has been almost entirely indirect, mediated by news coverage, Internet postings, informal conversations, and documentaries and video footage of events in distant regions (such as melting glaciers in Greenland) that describe these events in relation to climate change.

Media reporting follows rules different from those of science. Accurate description of the world is only one objective of an enterprise that also seeks to maximize audience share and to conform to the interests or values of the media outlet's owners or advertisers (Hoggan, 2009; Hulme, 2009). American news media tend to frame stories dramatically (e.g., as impending dangers or as controversies with two sharply opposing sides) and to report "breaking" news stories in preference to stories of slow-onset or chronic phenomena. These concerns and routines can introduce bias, but most audience members have limited resources to evaluate the accuracy and motivation behind media reports. Accurate or not, media reports influence people's thoughts and feelings (Krosnick & Kinder, 1990). The long tradition of psychological research in risk communication has included studies of the effects of risk messages about climate change impacts (e.g., Moser & Dilling, 2007; O'Connor, Bord, Yarnal, & Wiefek, 2002).

In the climate policy debate, the American mass media have, sometimes inadvertently, promoted the view that even aspects of climate change that are uncontroversial among scientists are matters of serious scientific debate (Boykoff & Boykoff, 2004). On one side of the controversy portrayed in the media are predictions emanating from some environmental movement organizations, supported by scientists concerned about the potential consequences of climate change, of catastrophes resulting from climate change, including famine and political instability in developing countries, loss of species and ecosystems, and new public health disasters. Advocates have publicized vivid images of the future they fear, in films such as *An Inconvenient Truth* (David, Bender, Burns, & Guggenheim, 2006), and emphasized the growing scientific consensus about many climate change conclusions and the human responsibility for climate change. This narrative emphasizes elements of dread and unknown risk, which induce concern and make for a dramatic media story, and activates personal moral norms to act to reduce such risks through its claims that negative consequences from climate change will be large and highly probable and that people are responsible. This view has sometimes been characterized as a "Pandora's box" frame (Nisbet & Scheufele, 2009). By suggesting that future catastrophe is certain unless action is taken, it goes beyond what many scientists consider defensible. However, the idea that continued emissions of greenhouse gases increase the likelihood of catastrophe is entirely consistent with scientific knowledge (National Research Council, 2010a).

The "other side" presented by the media presents various forms of reassuring pictures of the future and critiques of climate science. Such accounts tend to cite (a) the small number of legitimate scientists who interpret the existing evidence base on climate change from a skeptical perspective, focusing more on existing uncertainty about future climate events and their consequences for human welfare than on the potential downside risk of these uncertain events, as well as (b) less scientifically expert sources (see Footnote 2) engaged in an ongoing movement in the policy world to deny the reality and recently, even the science, of climate change. This movement has been funded by some major oil and gas companies and wealthy conservative individuals and is largely implemented by conservative think tanks (Dunlap & McCright, 2010; Hoggan, 2009; McCright & Dunlap, 2003). It has been guided by research conducted for Republican Party strategists and aided by a small number of contrarian scientists, several of the most prominent of whom were veterans of an earlier, industry-funded campaign to minimize the health effects of tobacco smoke (Oreskes & Conway, in press). Not organized from a single place, these efforts are best characterized as an elite-driven social movement to shape public perceptions, interpretations, and concerns, motivated by objectives that include a desire to maximize the welfare of corporations in the fossil fuel sector and an ideological opposition to federal regulation, which movement proponents see as the likely consequence of a national commitment to contain climate change (Hoggan, 2009).

The climate change denial movement has promoted a number of beliefs about the physical phenomena of climate change that, if widely accepted, are likely to favor the movement's policy objectives: the beliefs that climate change is not happening or has not yet been demonstrated to be happening; that if it is happening, its causes lie in natural phenomena rather than human activity; that its consequences will be familiar and relatively mild (e.g., a small increase in average temperature); and that actions to limit greenhouse gas emissions will be catastrophic for economic and other widely held values.

An important part of the denialist framing has been to characterize the science concerning the existence, causes, and consequences of climate change as "uncertain" and to suggest that "uncertainty" means that the global climate may not be changing and that delays in action are therefore prudent. The policy argument is that it is unwise to undertake expensive "fixes" to a problem that may not exist and that action should wait until the science is definitive. The denial movement has emphasized scientific uncertainty by publicizing events and evidence that appear to contradict parts of the scientific consensus. It has exploited the propensity in U.S. journalism to cover controversies by presenting its view of climate change as "the other side of the story." The influence of this "scientific uncertainty" frame has probably increased as a result of economic pressures on news outlets, which have thinned the ranks of science journalists and left fewer professionals with time to develop informed judgments about which factual claims have enough veracity to deserve serious coverage.

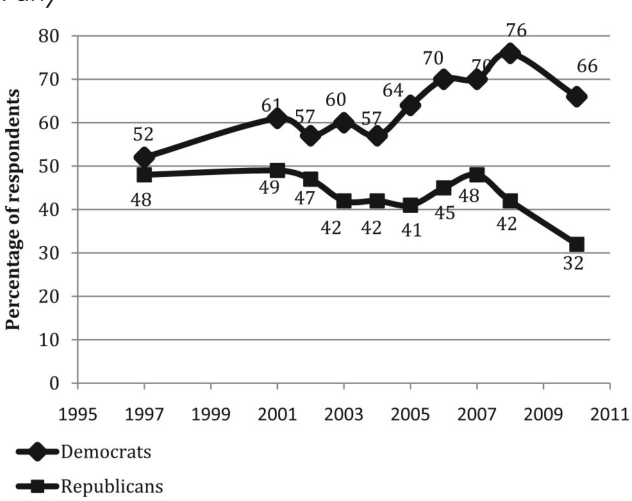
In the fall of 2009, denialists publicized a few errors in the 2007 IPCC reports and some e-mail correspondence between individual climate scientists that appeared to suggest the selective and biased reporting of climate data. While errors in a scientific report and the behavior of a small number of scientists are regrettable, neither of the events appears to warrant their use in the framing of climate change as a conspiracy by liberal politicians and grant-seeking scientists, thereby generally discrediting the enterprise of climate change science. The report of the United Kingdom's House of Commons Science and Technology Committee (2010) cleared the University of East Anglia's Climatic Research Unit from any charges of tampering with data or perverting the peer review process to exaggerate the threat of global warming. A review by the InterAcademy Council (2010), a group of 12 National Academies of Science, prompted in part by the revelation of errors in the last IPCC assessment, found the IPCC's review process sound and thorough but recommended stronger enforcement of existing IPCC review procedures to minimize future errors. Despite these and other rebuttals of charges of a climate conspiracy, continued allegations have allowed the denialist movement to block national policy action in the United States since the 1990s, in spite of a growing scientific consensus and initially supportive public opinion (McCright & Dunlap, 2003).

The denialist narratives effectively apply psychological knowledge about risk perception and the bases of environmental concern. They question the accuracy of isolated pieces of evidence, with the implication that the entire construct of climate change will fall like a house of cards (Pollack, 2007). They portray the risks of climate change as natural, familiar, and improbable—characteristics associated with low risk perception and concern (Slovic, 1987). In the terms of norm-activation theory, they deny negative consequences of climate change for people, claim that human actions are not responsible, and further assert that actions to limit climate change will be responsible for strong negative consequences (for the economy and jobs). These claims tend to counteract moral norms to reduce emissions and to activate morally based opposition to emissions reduction efforts.

Such arguments about climate risks have been described in an influential line of research under the rubric of "social amplification of risk" (e.g., Kasperson et al., 1988; also see Hulme, 2009). The arguments of opposing sides reflect opposing value priorities. The denialist narratives appeal to "self-enhancement" values (Schwartz, 1994) and are most strongly propounded in American politics by opponents of government regulation of business and defenders of individualism. The environmental disaster narratives appeal to an opposing set of "self-transcendent" or "biospheric-altruistic" values that emphasize collective and ecological well-being (see Stern et al., 1999). Thus, acceptance of the more alarmist climate narratives has been associated with liberal politics, just as acceptance of the denialist narratives has been associated with conservative politics (Leiserowitz, Maibach, & Roser-Renouf, 2008). Information sources in the media have promoted climate change narratives in line with their ideological leanings. Not surprisingly, U.S. public opinion has become polarized over time along liberal–conservative lines and by political party identification (McCright & Dunlap, in press), as shown in Figure 2.

In this debate, some advocates on both sides have tried to take advantage of widespread confusion of climate with weather and have cited notable weather events as evidence for their views on climate change. Thus landfalls of particularly powerful hurricanes on the U.S. mainland have been cited as evidence of climate change, and unusual cold snaps or snowfalls have been cited as evidence against it. Such arguments are much more likely to come from politicians and policy advocates than from scientists. Such experiential but essentially irrelevant evidence is particularly influential with members of the public (about 30% of the U.S. population) who have little trust in science and scientists (Malka & Krosnick, 2009). Advocates have also tried to shape attitudes toward policy options by giving favorable labels to their favorite policies (e.g., "green jobs" or "clean coal"). Such framings can be effective. For example, Hardisty, Johnson, and Weber (2010) found that 65% of Republicans were willing to pay a CO_2 emission reduction fee on airline tickets when the fee was labeled a carbon *offset* but that this percentage dropped to 27% when the fee was labeled a carbon *tax*.

Figure 2
Percentages of American Respondents Saying That the Effects of Global Warming Have Already Begun, by Party



Note. Percentages of American respondents indicating in Gallup polls taken between 1997 and 2010 that they believed that the effects of global warming had already begun or would begin within a few years are shown as a function of self-described political affiliation (diamonds for Democrats and squares for Republicans).

Even though a (slight) majority of Americans accept the idea that climate change is occurring and is anthropogenic (as shown in Figure 1), the effects of the struggle over framing can be seen in a recent decline in the level of acceptance and especially in the increasing ideological polarization of climate change beliefs in the U.S. public, most strongly evident among people who consider themselves well-informed (Dunlap & McCright, 2010). Leiserowitz et al. (2008), on the basis of large online surveys that assessed respondents' world views as well as perceptions and attitudes toward climate change, described the U.S. public as divided into distinct "interpretive communities," each with its characteristic risk perceptions, affective imagery, values, and sociodemographic characteristics. From climate change naysayers (who perceive climate change as a very low or nonexistent danger) to climate change alarmists (who hold high-risk perceptions and extreme images of catastrophic climate change) and other groups in between, each subpopulation holds significantly different values and beliefs on social and political issues and different views on the need for individual behavioral change and governmental intervention. This pattern is consistent with the above analysis of a public confronted with complex physical phenomena that cannot be understood without mediated knowledge, subject to normal cognitive and affective limitations, and surrounded by a politicized struggle to shape understanding that is amplified by polarized media that offer knowledge claims congenial to selected audiences' goals, values, and worldviews.

It is important to emphasize that this U.S. story has not been the global one. In many other countries, public understanding appears to be much closer to scientific understanding than is the case in the United States. Until relatively recently, the denialist movement has also been almost uniquely a U.S. phenomenon, judging from the national origin of denialist books (Dunlap, 2009). Recently, it has been globalizing. There has been a sharp increase in the publication of such volumes in other countries, starting in the United Kingdom, and public opinion data there are showing corresponding small decrements in acceptance and concern, as shown in Figure 1.

The Future of Public Understanding and Its Relation to Action

The trajectory of public understanding frustrates many climate scientists and educators who see climate risks growing, understand that delayed action will increase the risks further, and believe that concerted action is needed now to reduce them (e.g., Hansen, 2009). Many of these concerned individuals see climate literacy and continuing efforts by scientists to explain what they know as the way to accomplish the objectives of improved public understanding, increased public concern about climate change, and increased public support and action to reduce climate risks. However, unless existing behavioral science evidence collected in different domains of application is brought to bear on climate literacy and education, there is no reason to believe that future efforts will be any more successful in improving public understanding or willingness to take action related to climate change than past efforts have been. Conventional educational and informational programs are unlikely to have a major effect on aggregate public opinion, and more effective strategies need to be devised to improve public understanding and to increase individual and collective action. As political ideology plays a large role in people's beliefs about climate change and their policy support, problems with public understanding are not mainly due to a knowledge deficit but often result from a deficit in trust in the conveyors of climate models and data (Malka & Krosnick, 2009).

Improving Public Understanding

Public understanding of climate change needs improvement, but the problem is not one of "illiteracy." In comparison to the rest of the world, the American public has an average amount of knowledge about climate change and an average understanding of climate change phenomena (Brechin, 2003). U.S. adults who doubt that climate change is happening, is anthropogenic, or presents serious risks should be assumed not to have a deficit of knowledge but rather to have different understandings. Individuals holding mental models that conflict with the available scientific evidence are not a blank slate, as the metaphor of illiteracy suggests, so the needed educational process is not one of adding to knowledge but one of inducing conceptual change. Research on science education indicates that preconceptions that conflict with scientific understanding can be tenacious and that instruction that does not address them typically fails to help learners adopt mental models that are scientifically accurate (National Research Council, 2005). A developing literature, focused mainly on teaching fundamental scientific concepts to children, identifies common preconceptions in some areas of science and studies "learning progressions" that can lead learners effectively from their preconceptions to mental models that are consistent with scientific understanding (National Research Council, 2007). Changing adults' misconceptions about climate change will likely prove more difficult than teaching children, but the general principle of beginning with learners' preexisting mental models surely applies (Bostrom et al., 1994; Kempton, 1991). What can scientists and educators do to improve U.S. public understanding? We begin by stating a position in favor of "nonpersuasive communication" (Fischhoff, 2007). Much of value can be gained by efforts to inform the public in ways that are not disguised efforts to engage support for a line of public policy. Thus, it is important for scientists to continue to explain what is and is not known about climate change to journalists, policymakers, and the general public, using normal science education approaches, and to explain the difference between reducible versus irreducible uncertainty. Such efforts will be valuable to people whose understandings already approximate those of scientists, whose understandings are relatively unformed, or who become more open to input from scientists in the future. It is also important to continue to correct errors and mischaracterizations of the science of climate change, which continue to be publicized despite repeated corrections. These efforts are necessary, though unlikely to be sufficient, to raise the level of public understanding in the current politicized environment.

Other approaches are needed in addition. One is to explain a simple conceptual frame for understanding climate change that is more congruent with the state of knowledge than the persuasive frames on offer now—a frame that does not claim too much for the ability to make climate predictions or exaggerate the import of existing scientific uncertainties.[7] Recent scientific reports are beginning to define such a frame—one that emphasizes risk or uncertainty management (Gober, Kirkwood, Balling, Ellis, & Deitrick, 2009; National Research Council, 2009, 2010a, 2010b, 2011; Pollack, 2007). In this frame, climate change is shown to alter the profile of risks from the many events associated with climate, typically increasing such risks, including catastrophic ones. Responses to climate change are presented as options for risk management, not as self-evident responses to a predictable future.

The risk management frame is readily understandable. Everyone faces catastrophic risks (from life-threatening diseases, automobile accidents, house fires, and even climate-related events), and everyone understands strategies for managing them. One strategy is to reduce activities that might lead to catastrophe (e.g., controlling our diets, staying off icy roads, or for climate change, adopting energy-efficient and low-emissions technology). Another is to lower the cost of catastrophic events if they occur (e.g., installing air bags and fire extinguishers, buying health and fire insurance, or, with climate change, protecting vital infrastructure and improving early warning and emergency response capabilities). Yet another strategy is to invest in a better understanding of the risk profile and of the likely costs and benefits of the risk management options. People manage risks by employing combinations of these strategies or by employing none of them and taking their chances.

[7] Pidgeon and Fischhoff (2011) provide numerous concrete suggestions for how to better communicate uncertain climate risks.

In this frame, the role of science is to help characterize the risks, show how risk profiles are changing, and assess the consequences of the response options and thus inform decision making. Science has been doing this by establishing important fundamental facts about past and current climate and about the processes that govern climate change. Science has also been improving its capability to describe risk profiles, that is, to estimate how climate change—and human responses to it—will affect the likelihood and intensity of various outcomes of concern.

We believe that people who understand climate science as providing information about risk profiles will be well prepared to interpret new information as knowledge develops about climate change and the options for response. They will not expect more precise predictions than science can offer, and so, when a single event seems to go against a predicted trend, might realize that this does not question the entire scientific enterprise.

Information about risk profiles does not offer predictions, but it still can be very useful for practical decision making. For example, Gober et al. (2009) presented a set of scenarios of future water availability in Phoenix, Arizona—an area that climate change will make more arid—based on varying policy decisions superimposed on a range of peer-reviewed climate models. Despite uncertainties about both climate and policy, participants in a simulation exercise were able to reach several important policy-related conclusions, including that current levels of water consumption are unsustainable under most climate scenarios and that feasible reductions in residential water use would allow the region to weather even the most pessimistic climate projections if action begins soon.

A second approach to improving understanding emphasizes providing better mental models, that is, understandings that accurately convey the essence of what is and is not known about climate risks and that counteract prevalent misconceptions. Some important misconceptions were identified above and suggest the following key elements of a better mental model (National Research Council, 2009, 2010a, 2011): (a) Future climate will be unlike the climate at any time in the 10,000 years of recorded human history. (b) The global climate is a complex system that may have tipping points or thresholds that, once crossed, lead to irreversible events. Major climate "surprises" cannot be ruled out. (c) Climate change is not a single hazard like a hurricane or heat wave but a process that changes the likelihood of many hazards. (d) Personal experience is a misleading guide to climate change. (e) Climate change processes have considerable inertia and long time lags; thus, either action or delay now will shape the world for generations. These insights reflect some of the important established facts about climate change, selected to directly counter common misconceptions, such as that the future will be much like the past; that even after extreme events, things will return to normal; that recent weather signals global trends; that if we just reduce greenhouse gas emissions, we can solve the problem fairly quickly, as we did with urban smog and the "ozone hole"; and that waiting for scientific certainty is a low-cost option.

Climate scientists, educators, and psychologists need to find effective ways to replace misleading frames and mental models with ones that more accurately reflect both what science knows and the limits of scientific understanding. More research is needed to find the most important mental model elements and the best learning paths from erroneous ideas to ones more consistent with the science. It may be necessary to confront inappropriate mental models explicitly, perhaps using dialogue formats. It may sometimes be useful to present climate change information in terms of risk profiles combined with scenarios. It may be useful to draw analogies to other domains of risk and uncertainty (health/cancer, time and circumstances of death, financial circumstances at retirement) and provide demonstrations of the value of protective or preventive action (Weitzman, 2007).

Even strong efforts to teach better frames and mental models may not yield rapid improvement in public understanding. Resistant mental models, cognitive and emotional investments in current understandings, misguided media attempts at balanced coverage, and the vigorous campaign to deny the science are major barriers to change. It may take noneducational scenarios to shake up thinking on a relatively short time scale. One such scenario depends on climate-related catastrophe. Beliefs in climate change are affected by local weather conditions (Li et al., 2011), and a relatively cool 2008 may have influenced the drop in American concern about climate change in 2008–2009 (Woods Institute for the Environment, 2010). Recency effects can work in the other direction as well. An event or string of climate-related events might shift public opinion if it is vivid and catastrophic, if it strikes in the United States and gets intense media coverage, and if it fits a widely held mental model of climate change (e.g., a deadly heat wave like the one in Europe in 2003 might be widely attributed to climate change, but a catastrophe from floods or forest fires might not). This scenario might increase concern about climate change, but ironically, it would depend on the erroneous equation of climate and weather.

Another scenario for change involves leadership by elites in major corporations and the national security establishment who are already changing their thinking. Many major corporations already accept that climate change is happening and see the need to adapt or the opportunity to profit by offering new products and services (Global Roundtable on Climate Change, 2007). The U.S. national security and intelligence communities have come to see climate change as a security threat and are preparing to adapt (U.S. Department of Defense, 2010). If such actors become more publicly engaged, the balance of media coverage may begin to change in ways that affect public understandings nationally.

Yet another scenario for improving understanding relies not on transmission of information but on two-way communication and the engagement of people in practical decisions, particularly related to resilience to climate change. Climate change may call for different decisions to be made in domains from land use planning in coastal zones to the redesign of storm water systems to strategies for protecting endangered species (National Research Council, 2009). Participants in these decisions will need a good working knowledge of climate change, at least as it relates to those decisions. Efforts to provide such understanding, often called decision support, can be effective if based on an understanding of the ways the intended audiences think about climate change and if developed through processes that engage the decision makers in developing working knowledge (Center for Research on Environmental Decisions, 2009; National Research Council, 1999, 2009). Simply "translating" climate science into less technical language without such understanding is likely to be inadequate, but well-designed decision support systems might actually improve public understanding.

From Understanding to Action

How might improved public understanding affect action on climate change? Understanding can affect concern and support for policies, as the struggle to frame the issue indicates. However, the effect of education and information on other kinds of action, such as household and organizational actions to reduce emissions directly, is likely to be quite limited. Research shows that such effects are usually weak at best because of noninformational barriers to behavioral change (G. T. Gardner & Stern, 2002; Stern, 2011, this issue).

All the evidence suggests that trying to alter understanding is not an efficient way to induce people to act personally to reduce climate risks. Lack of understanding and concern is not the limiting factor. Public support for policies to reduce fossil fuel consumption (61%–87% depending on the policy) is much stronger than public belief that climate change is anthropogenic (50%) (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2010). Many people already accept low-carbon energy policy objectives and are willing and able to assimilate good information on how to reduce their emissions regardless of what they understand about climate change. Much is known about how to increase environmentally significant behavior (see Stern, 2011). Efforts along these lines need not depend on changing public understanding and might help promote widely accepted policy goals without invoking the difficult politics of climate change.

An Expanded Role for Psychology

Psychology as a discipline has played only a minor role in contributing to our current understanding of the American public's knowledge and attitudes about climate change and their ability and willingness to take action. Studies that examine public knowledge about behaviors that reduce energy consumption (Attari, DeKay, Davidson, & Bruine de Bruin, 2010), for example, are more likely to be conducted by engineers or management consultants than by psychologists. Many of the studies cited above to support assumptions about people's information processing related to climate change beliefs and actions were conducted in different domains, many of them using abstract stimuli (e.g., monetary lotteries) and conducted in lab settings. Although such studies and their results can be instructive in providing research hypotheses, there is a large need for psychological research that tests these hypotheses in the climate change domain and in field settings. There is also a strong need for comparative studies conducted across countries and cultures that differ on socioeconomic, political-ideological, and other dimensions. Too much of psychological theory and lore is based on experiments conducted with privileged undergraduates at American universities. Success in dealing with climate change in the long run on a global scale will depend in part on developing a better understanding of cultural differences in values, beliefs, and goals that influence climate change perceptions and actions.

Psychology can also provide more and better input into educating both the general public and influential intermediaries such as journalists about climate change. The distinction between learning from experience versus learning from description needs to be explored more in the context of learning about future possible common as well as rare consequences of climate change. Given the long time horizons with which such experiential feedback would be provided by the "real world," psychology could collaborate with designers of virtual realities to design test beds for its theories and to design learning environments that can significantly shorten the feedback cycle as well as provide members of the public with means to experience the consequences of uncertainty, including climate futures that include catastrophic events that may be quite unlikely but that deserve consideration in long-term planning. Examples of such tools exist in other domains; for example, the Distribution Builder tool (Goldstein, Johnson, & Sharpe, 2008) provides individuals who are considering different pension saving rates and instruments with experiential feedback about the consequences of their decisions in a realistic simulation of the uncertainty associated with future financial investment returns. A realistic range of climate futures to use in such simulations will need to be worked out, with input from climate scientists, social scientists, and other experts in the physical, ecological, political, and socioeconomic processes that continuing climate change will set into motion.

The effectiveness of alternative frames to motivate climate-change-relevant action will need to be tested in different populations (e.g., age and income groups) in the United States and elsewhere; such testing will need to examine not just the frames' effectiveness but also the pathways and processes by which they succeed or fail to succeed to modify existing behavior. A review by Weber and Lindemann (2007) only touched on a subset of the decision processes identified by psychologists in different choice domains, and the effectiveness of rule- and role-based decision modes more typically studied in the domain of ethical or moral decisions needs to be systematically explored in the context of environmental and climate-change decisions (Weber, in press).

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